Tensile Strength – A Design And Evaluation Tool for Superpave Mixtures

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by

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Executive Summary

Evaluation of a mixture's moisture sensitivity is currently the final step in the Superpave volumetric mix design process. The presence of water (or moisture) often results in premature failure of asphalt pavements in the form of isolated distress caused by debonding of the asphalt film from the aggregate surface or early rutting/fatigue cracking due to reduced mix strength. The damage due to moisture is controlled by the specific limits of the tensile strength ratios (TSR) or the percent loss in tensile strength of the mix. Loss in the pavement strength due to moisture damage indicates that the individual tensile strength of the mixtures after conditioning will govern the rutting and fatigue life of the mixtures. A total dependency and reliance on the TSR values only may be misleading in many cases. There has been no concerted effort at national or state level towards establishing the quantitative causal effects of failing to meet the minimum prescribed value of TSR or loss in tensile strength. Tensile strength plays an important role in the performance of a mixture under fatigue, rutting and moisture susceptibility. A recent pilot research study conducted at NCSU has shown that there exists a relationship between the indirect tensile strength of a mixture and its estimated fatigue and rutting life. A minimum tensile strength value can be calculated at a given traffic level for fatigue life and an allowable rut depth for rutting and can be used as an additional criterion for evaluating the moisture susceptibility of a mix. ***Thus, the individual values of tensile strength of conditioned and unconditioned specimens along with TSR values should be employed in assessing the effect of water damage on the performance of pavements.***

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Introduction and Problem Statement

Many factors contribute to the degradation of asphalt pavements. When high quality materials are used, distresses are typically due to traffic loading, resulting in rutting or fatigue cracking. Environmental conditions such as temperature and water can have a significant effect on the performance of asphalt concrete pavements as well. The presence of water (or moisture) often results in premature failure of asphalt pavements in the form of isolated distress caused by debonding of the asphalt film from the aggregate surface or early rutting/fatigue cracking due to reduced mix strength. Moisture sensitivity has long been recognized as an important mix design consideration.

Probably the most damaging and often hidden effect of moisture damage is associated with reduced pavement strength. Tensile strength plays an important role in the performance of a mixture under fatigue, rutting and moisture susceptibility. The damage due to moisture is controlled by the specific limits of the tensile strength ratios (TSR) or the percent loss in tensile strength of the mix. The moisture sensitivity of a mixture is evaluated by performing the AASHTO T-283 test. This test has a conditioning phase, where the sample is subjected to saturation and immersion in a heated water bath to simulate field conditions over time. Strength loss is then evaluated by comparing indirect tensile strengths of an unconditioned control group to those of the conditioned samples. If the average retained strength of the conditioned group strength is less than eighty-five percent of the control group strength, the mix is determined to be moisture susceptible. This indicates that the combination of asphalt aggregate would fail due to water damage during the early part of the service life of the pavement. Moreover, a total dependency and reliance on the TSR values only may be misleading in many cases. For instance, let us review the hypothetical TSR data for two different mixtures (A and B) in Table 1.

Table 1 Hypothetical TSR Data

Mix	Tensile Strengths (psi)		TSR (%)
	Unconditioned	Conditioned	
A	200	156	78
B	100	84	84

The mixtures A and B have TSR values of 78% and 84%, respectively. Even though both the mixes do not meet the criteria of a minimum TSR value of 85%, the conditioned tensile strength of a mix A is 56% higher than the unconditioned tensile strength of mix B. Furthermore, the effect of using mix A will not be as detrimental on the pavement performance as compared to the case if mix B were to be used as a surface course in a given pavement structure. It is evident that individual tensile strength of the mixtures after conditioning will govern the rutting and fatigue life of the mixtures. A total dependency and reliance on the TSR values only may be misleading in many cases. There has been no concerted effort at national or state level towards establishing the quantitative causal effects of failing to meet the minimum prescribed value of TSR or loss in tensile strength. ***The individual values of tensile strength of conditioned and unconditioned specimens along with TSR values should be employed in assessing the effect of water damage on the performance of pavements.***

Thus, the tensile strength is one of the critical parameters to be always taken into consideration for performance evaluation. The evaluation of the fatigue life of a mixture is based on the flexural stiffness measurements. Tensile strain at the bottom of the asphalt concrete layer in a pavement is an important parameter in the measurement of fatigue life of a mixture. The bottom of asphalt concrete layer has the greatest tensile stress and strain. Cracks are initiated at the bottom of this layer and later propagate due to the repeated stressing in tension of asphalt concrete pavements caused by bending beneath the wheel loads. Ultimately, the cracks appears on the surface in the wheel paths which we characterize as fatigue cracking.

The tensile strength is primarily a function of the binder properties. The amount of asphalt binder in a mixture and its stiffness influence the tensile strength. Tensile strength also depends on the absorption capacity of the aggregates used. At given asphalt content, the film thickness of asphalt on the surface of aggregates and particle to particle contact influences the adhesion or tensile strength of a mixture. Various studies have repeatedly proved that the tensile strength increases with decreasing air voids. The tensile strength of a mixture is strongly influenced by the consistency of the asphalt cement, which can influence rutting. Thus, tensile strength plays an important role as a design and evaluation tool for Superpave mixtures.

A recent pilot research study conducted at NCSU has shown that there exists a relationship between the indirect tensile strength of a mixture and its estimated fatigue and rutting life. Correlations can be developed between the indirect tensile strength and performance parameters of mixtures. A minimum tensile strength value can be obtained from these correlations below which the mixture would not perform at a desired level of serviceability. The indirect tensile strength values could be ready for immediate adoption for mix design and QA/QC purposes.

In view of the above reasoning, it is of paramount importance that a minimum tensile strength value based on the fatigue and rutting life of a mixture in conjunction with TSR values should be employed in assessing the effect of water damage on the performance of pavements.

The use of lime to reduce moisture sensitivity has been promoted by FHWA for many years. While reviewing the records of Hot Mix Asphalt concrete (HMAC) mixtures produced in the early 1960's and today, a major difference was identified as the lack of mineral fillers in today's mixes. These fillers increase film thickness, improve the cohesion of the binders and increase the stiffness of the mixtures. A recent study indicated that the addition of hydrated lime as mineral filler improved the permanent deformation characteristics and fatigue endurance of the asphaltic concrete mixtures. This improvement was particularly apparent at higher testing temperatures with mixes containing polymer modified asphalt and limestone aggregate. At the same time, Lime had a few problems in the field as there were instances that the contractors have complained about personnel exposure and problems handling lime. So the performance of lime as an anti-stripping agent should be compared with the performance of a liquid anti-stripping agent. The difference in the performance of these two anti-stripping agents should be studied.

Research Objectives

The primary objectives of this research study will be to:

1. Evaluate the tensile strengths of conditioned and unconditioned specimens and their tensile strength ratios (TSRs) for mixtures with different aggregates and gradations.
2. Conduct a comparative study on the effects of hydrated lime and a liquid anti-stripping agent on tensile strength and TSR values of the mixtures.
3. Develop the relationship between the tensile strength for mixtures with different aggregates and gradations and their fatigue performance as estimated using the Frequency Sweep Test at Constant Height, Diametral Tensile Fatigue Test and Indirect Tensile Test.
4. Conduct a detailed study to investigate the rutting performance of mixtures with different aggregates and gradations using the Repeated Shear Test and Constant Height and develop its relationship with the tensile strengths of the mixtures.
5. Develop a minimum tensile strength criterion along with TSRs for mixtures with different aggregates and gradations.

Background and Literature Review

Stripping of an asphalt concrete mixture takes place when adhesion is lost between the aggregate surface and the asphalt cement. The loss of adhesion is primarily due to the action of moisture. Modes of failure, as a result of stripping, include raveling, rutting, shoving and cracking. The Superpave mix design system incorporates a test for moisture sensitivity as part of the mix design process. The goal in a mix design is to accurately predict a mixture's propensity to strip while in service. To better understand the theories and principles currently utilized, a detailed discussion is presented.

Theories of Moisture Susceptibility

The moisture affects asphalt mixes in three ways: loss of cohesion, loss of adhesion, and aggregate degradation. The loss of cohesion and adhesion are important to the process of stripping. A reduction in cohesion results in a reduction in strength and stiffness. The loss of adhesion is the physical separation of the asphalt cement and aggregate, primarily caused by the action of moisture. The air void system in the asphalt concrete provides the means by which moisture can enter the mix. Once moisture is present through voids or from incomplete drying during the mixing process, it interacts with the asphalt-aggregate interface.

Theory of Adhesion

The loss of adhesion is explained in current literature using one or a combination of four theories. The theories include chemical reaction, mechanical adhesion, surface energy and molecular orientation. Chemical reaction is a possibly mechanism for adhesion of the asphalt cement to the aggregate surface. Research indicates that better adhesion may be achieved with basic aggregates than with acidic aggregates but, acceptable asphalt mixes have been made with all types of the aggregate. Recent studies concentrating on the chemical interactions at the asphalt aggregate bond have found adhesion to be unique to individual material combinations. Mechanical adhesion depends primarily on the physical properties of the aggregate such as surface texture, surface area, particle size and porosity. A rough porous surface absorbs asphalt and the greater surface area promotes greater mechanical interlock. The surface energy theory explains the wettability of the aggregate surface by the asphalt and water. Water has a lower viscosity and lower surface tension than asphalt cement and thus a better wetting agent. The final theory is regarding the molecular orientation, according to which molecules of asphalt align with aggregate surface charges. Since water is entirely dipolar, there exist a preference for water molecules over asphalt.

Current literature suggest seven factors that affect adhesion and were used to develop the theories:

1. Surface tension of the asphalt cement and aggregate
2. Chemical composition of the asphalt cement and the aggregate
3. Asphalt viscosity
4. Surface texture of the aggregate
5. Aggregate porosity
6. Aggregates cleanliness
7. Aggregate moisture content and temperature at the time of mixing

Theory of Cohesion

Cohesion is defined as the molecular attraction by which the particles of a body are united throughout the mass. In compacted asphalt concrete, cohesion may be explained as the overall integrity of the material when subjected to load or stress. On a micro scale, in the asphalt film surrounding, the aggregate, cohesion can be considered the resistance to deformation under load that occurs at a distance from the aggregate, beyond the influences of mechanical interlock and molecular orientation. If the adhesion between aggregate and asphalt is adequate, cohesive forces will develop in the asphalt matrix. It may be thought of as the initial resistance since it is independent of applied load. Quantitatively, cohesion is the magnitude of the intercept of the Mohr envelope in a Mohr Diagram. A loss of cohesion is typically manifested as softening of the asphalt mixture.

Cohesive forces are influenced by the mix properties such as viscosity of the asphalt-mineral filler system. The cohesive forces in an asphalt concrete mix are inversely proportional to the temperature of the mix. Typically the stability test, resilient modulus test or tensile strength test measures cohesive resistance. A mechanical test such as the tensile strength test primarily measures overall effects of moisture-induced damage. As a result, the mechanisms of cohesion and adhesion cannot be distinguished separately in the test results.

Factors Affecting Moisture Susceptibility

In many cases, in-place properties and service conditions of HMA pavements induce premature stripping in asphalt pavements. An understanding of these factors is important to investigate and solve the problem of moisture-induced damage. Three indicators of stripping, white spots, fatty areas, and potholes, usually start at the bottom of the HMA layer and continue upward. The surface of the pavement is exposed to high temperatures and long drying periods whereas the bottom of the HMA layer experiences longer exposures to moisture and lower temperatures.

Mixture Consideration

The physio-chemical properties of the aggregate are important to the overall water susceptibility of an asphalt pavement. Chemical and electrochemical properties of the aggregate surface in the presence of water have a significant effect on stripping. Aggregates that impart a high pH value to water are more susceptible to stripping. These aggregates are classified as hydrophilic, or water loving. A hydrophobic aggregate typically exhibit low silica contents and is generally basic. Hydrophobic aggregates such as limestone provide better resistance to stripping.

Excessive dust coating on the aggregate can prevent a thorough coating of asphalt cement on the aggregate. Fine clays may also emulsify the asphalt in the presence of water. Both conditions increase the probability of an asphalt mix to strip prematurely. High moisture contents in the mineral aggregates before mixing with the asphalt cement can also increase the potential for stripping. However, most states require adequate temperatures to assure dry aggregate. Degradation of aggregate HMA mixes also contributes to stripping. Broken aggregates from compacting and traffic loading expose new surfaces. These uncoated surfaces absorb water and initiate premature stripping.

The viscosity of the asphalt does play a role in the propensity of the asphalt mix to strip. It has been documented that high viscosity asphalt resists displacement by water better than those that have a low viscosity. High viscosity asphalt provides a better retention of asphalt on the aggregate surface. However, a low viscosity is advantageous during mixing because of increased coatability, providing a more uniform film of asphalt over the aggregate particles. Based on the theory of adhesion presented earlier the properties of asphalt cement and aggregate materials directly influence the adhesion developed between the mix components.

The type of HMA has been related to the water susceptibility of mix. Open graded base courses and surface treatments comprise the majority of pavement failures due to premature stripping. Both mixes are more permeable to water when compared to dense graded mixes. Surface treatments have been observed to be particularly susceptible to stripping. A well compacted, dense graded hot mix provides better moisture resistance. Water susceptibility can be further minimized with full depth asphalt pavement. Dense graded bases found in full depth pavements act as a moisture barrier between the subbase and the surface course.

Current Test methods Utilized for Evaluation of Moisture Susceptibility

Numerous test methods have been developed and used to evaluate the moisture susceptibility of HMA mixes. Tests for stripping are used to assess the following:

- The degree of moisture sensitivity in asphalt mixes
- The benefits of anti-stripping agents to decrease water susceptibility in asphalt mixes

Typically the test for evaluation contains a conditioning phase and an evaluation phase. The conditioning phase simulates in service conditions that increases water sensitivity, usually this includes a period of exposure to moisture. The evaluation phase may be qualitative or quantitative. A qualitative test estimates water susceptibility by visual inspection, whereas a quantitative test measures a strength parameter. Often in quantitative testing, one sample is conditioned and another tested dry, then a ratio is computed for conditioned strength versus unconditioned strength. Under the SHRP method of mix design, the Modified Lottman test (AASHTO T-283) was adopted and therefore, this test will be used to assess moisture susceptibility. In addition to this, Dynamic Indirect Tensile Test and Simple Shear Tester can also be used to evaluate the moisture sensitivity of asphalt mixtures. These tests are included as part of the experimental research plan in Table 2.

Research Methodology and Tasks

Task 1 – Materials and Superpave Mix Design

It is proposed that three aggregate types and two gradations would be used in this study and the mix designs would be conducted to meet the Superpave mix design criterion. Two anti-stripping agents including hydrated lime and a liquid anti-stripping agent would be used in this study. The effects of hydrated lime and the liquid anti-stripping agent on the tensile strength and TSR values of the mixtures would be evaluated. If any statistically significant difference exists between the performance of these agents, further tests for fatigue and rutting would be conducted on mixtures with both anti-stripping agents. If there is no significant effect between the performance of these agents, then the fatigue and rutting tests would be conducted for one of the two anti-stripping agents.

Task 2: Evaluation of Indirect Tensile Strength and Moisture Sensitivity

After the design of mixtures for optimum aggregate gradation and asphalt content, the moisture sensitivity of the mixtures will be evaluated. The calculation of the TSR in accordance to AASHTO T-283 is the standard method under the Superpave mix design system to evaluate a mixture's moisture sensitivity. A sample set will be conditioned by saturation and immersion to simulate the moisture damage of a mixture in field. The indirect tensile strengths of the unconditioned and conditioned sets will be compared to evaluate the moisture damage induced by conditioning. This loss of cohesion and adhesion manifests itself in a loss of tensile strength of a mix. The indirect tensile strengths of the mixtures in both conditioned and unconditioned states are measured from the Indirect tension test (IDT). The IDT test is described as follows:

Indirect Tension Test

The indirect tensile test is one of the most popular tests used for HMA mixture characterization in evaluating pavement structures. The indirect tensile test has been extensively used in structural design research for flexible pavements since the 1960s and, to a lesser extent, in HMA mixture design research.

The indirect tensile test is performed by loading a cylindrical specimen with a single or repeated compressive load which acts parallel to and along the vertical diametral plane. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametral plane which ultimately causes the specimen to fail by splitting along the vertical diameter as shown in Figure 1. A curved loading strip is used to provide a uniform loading width which produces a nearly uniform stress distribution. The equations for tensile stress and tensile strain at failure have been developed and simplified. These equations assume the HMA is homogenous, isotropic, and elastic. None of these assumptions are true, of course, but estimates of properties based on these assumptions are standard procedure and are useful in evaluating relative properties of HMA mixtures.

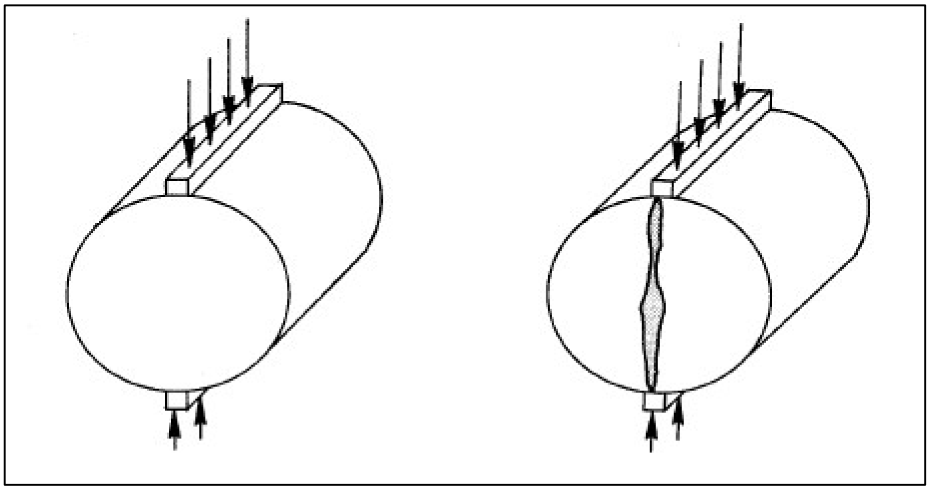

Figure 1. Indirect Tensile Test During Loading and at Failure

The equations for the indirect tensile stress and strain at failure are provided below:

$\sigma_x = 2P/\pi tD$

$\varepsilon_f = 0.52x_t$

where,

σ_x = horizontal tensile stress at center of specimen, psi

σ_y, = vertical compressive stress at center of specimen, psi

ε_f = tensile strain at failure, inches/inch

P =applied load, lbs.

d = diameter of specimen, inches

t = thickness of specimen, inches and

x_t = horizontal deformation across specimen, inches.

The above equation applies for 4-inch diameter samples having a 0.5 inch curved loading strip and for 6-inch diameter samples having a 0.75 inch curved loading strip. The indirect tensile test provides two mixture properties that are useful in characterizing HMA. The first property is tensile strength, which is often used in evaluating water susceptibility of mixtures. The IDT test with a repeated diametral loading would be conducted to evaluate the cracking potential of the mixtures. The sample is subjected to a repeated diametral loading force and the resulting horizontal diametral deformation is measured at an axis 90 degrees from the applied force. The tensile strain at failure is used to evaluate the cracking potential of the mixtures under fatigue.

Task 3: Performance Based Testing, Analysis of Service Life of the Pavements and its relation to Indirect Tensile Strength values

The mixtures will be evaluated for their resistance to fatigue and rutting performances. Performance evaluation tests will be conducted on both conditioned and unconditioned specimens to investigate the effect of moisture damage on fatigue and rutting characteristics of the mixtures. The indirect tensile strength values of the mixtures, measured from the IDT test, would be compared with the estimated fatigue and rutting parameters of the mixtures.

Task 3.1 Evaluation of Fatigue Performance

The Frequency Sweep test at Constant Height (FSTCH) and the Diametral repeated load test would be conducted on the mixtures to evaluate their fatigue life. The dynamic modulus values and phase angles measured from the FSCH test would be used in the surrogate models of SHRP to estimate the fatigue life of the mixtures. Similarly the test data from the diametral repeated load test would be used in the available fatigue cracking models for estimating the fatigue life of the mixtures. In either case, the stiffness of the mixtures and the tensile strain would be the governing parameters in the fatigue life estimation.

The specimens would be subjected to 0, 12 and 24 hours of conditioning which corresponds to 0, 0.5 and 1 cycle of conditioning, respectively. The tensile strengths of the mixtures would be measured at these cycles of conditioning. The shear tests and Diametral repeated load tests would be conducted on the specimens that are subjected to moisture damage at these different cycles. The fatigue life of the mixtures estimated from these performance evaluation tests would be correlated with the corresponding tensile strengths of mixtures. A minimum tensile strength criterion would be recommended for different traffic levels. A preliminary investigation shows that a minimum tensile strength exists for a given ESAL range, as shown in Figure 2. The fatigue life of the mixtures decrease exponentially with decreasing tensile strength. This trend is justified by the loss in stiffness and thereby initiating cracks and stripping. ***So, there exists a minimum tensile strength for a given ESALs level that can be used as a surrogate criterion for fatigue life estimation.***

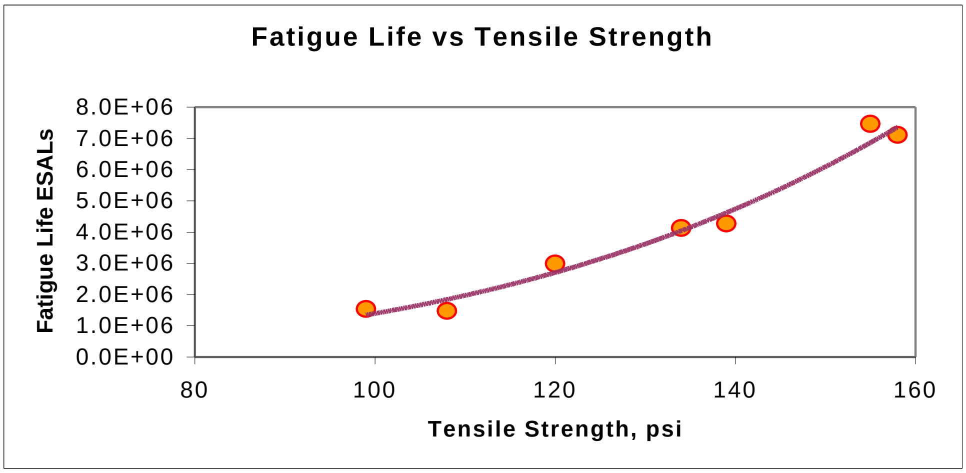

Figure 2. Fatigue Life of Mixtures with Different Tensile Strengths

Task 3.2 Evaluation of Rutting Performance

The repeated shear test at constant height (RSCH) is performed to identify an asphalt mixture that is prone to tertiary rutting. The accumulation of plastic shear strain in a mixture under repeated loading gives an indication about the mixture's resistance to rutting. The shear strain measured at the end of 5000 loading cycles would be used in SHRP surrogate rutting models to estimate the rut depths. A preliminary investigation shows that the mixtures with lower tensile strength have higher rut depths, as shown in Figure 3. It can be observed that the rut depths of mixtures increase with decreasing tensile strength, which can be attributed to the fact that the aggregate structure is affected due to moisture damage and subsequent loss in tensile strengths of the mixtures.

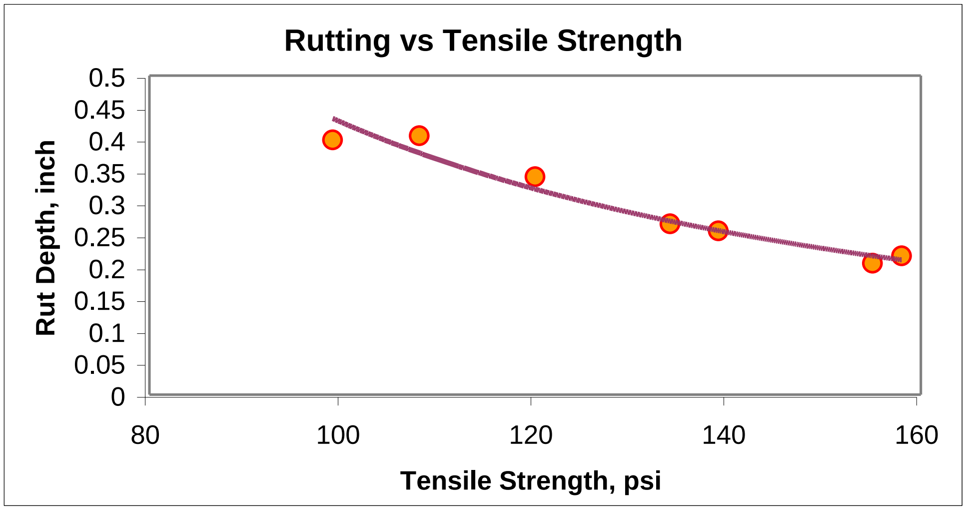

Figure 3. Rut Depths of Mixtures with Different Tensile Strengths

Task 4: Incorporation of Tensile Strength as a Design and Evaluation Tool for Superpave Mixtures

An experimental plan including the number of replicates for this proposed study is shown in Table 2. As mentioned in Table 2, the three gradations, two nominal sizes, two levels of conditioning and with and without two anti-stripping agents would be used in this research study.

The performance of the mixtures in fatigue, rutting and moisture is not affected by tensile strength alone. A large set of mixture properties influence the performance of the mixtures. Fatigue life of a mixture is influenced by the percent voids filled with asphalt (VFA), asphalt content, nominal maximum size of the aggregate, air voids etc., apart from the tensile strength and the stiffness of the mixtures. Similarly, the rutting characteristics of a mixture are influenced by the shear strength, air voids, percent voids in the mineral aggregate, asphalt content, percent aggregate fines than No.200 sieve, percent aggregate passing No.8 sieve and retained on No.200 sieve etc. The inherent influence of these factors would be investigated in detail using the statistical analysis. Regression and correlation analysis would be used to identify the statistically significant variables to be included in the relationship between tensile strengths of mixtures and their fatigue and rutting life. A General Linear Model (GLM) can be used in regression modeling of the factors for relating the fatigue or rutting life with a set of both qualitative and quantitative factors. The general form of the GLM is

$$y = a_0 + \sum_{i=1}^{n} a_i x_i + e$$

where,

y = the response variable, fatigue or rutting life

x_i = predictor variables such as tensile strength and other statistically significant variables, such as the percent voids filled with asphalt (VFA), asphalt content, nominal maximum size of the aggregate, air voids etc.,

a_0, a_1, a_2 … a_n = regression coefficients which measure the effect of predictor variables on the response variable

ε = random error that explains the variability of the responses

Thus, the relationships would be established between the tensile strengths of mixtures and their fatigue and rutting life. A minimum tensile strength value can be calculated at a given traffic level for fatigue life and an allowable rut depth for rutting, as shown in Figure 4. ***Thus, by using the recommended criteria, a minimum tensile strength value based on the fatigue and rutting life of a mixture in conjunction with TSR values should be employed in assessing the effect of water damage on the performance of pavements.***

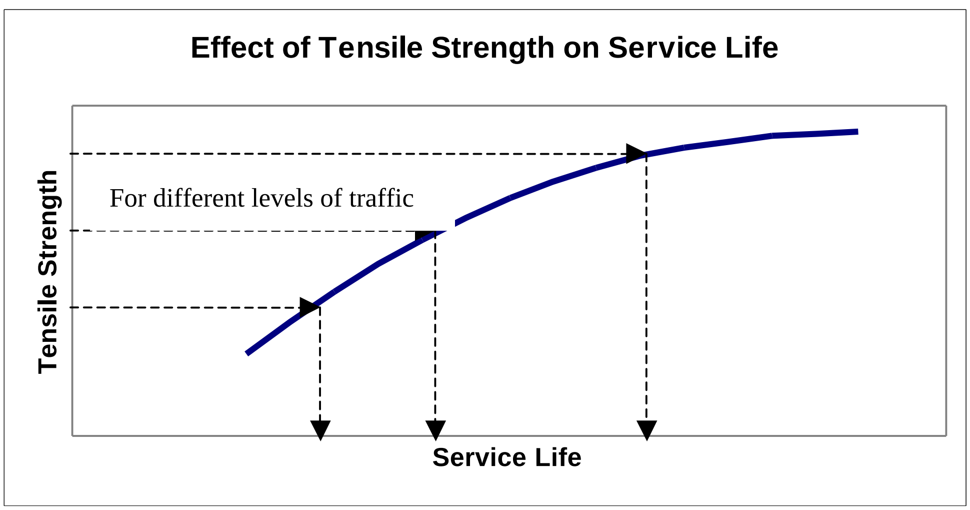

Figure 4. Typical Relationship between Tensile Strength and Service Life

Table 2. Experimental Plan

NMSA	Aggregate Source	Conditioning	Without Anti-Stripping Agent				With Anti-Stripping Agent			
			FSCH	RSCH	Diametral	IDT	FSCH	RSCH	Diametral	IDT
12.5mm	A	UC	3*	3	2	3	3	3	2	6
		HC	3	3	2	3	3	3	2	6
		FC	3	3	2	3	3	3	2	6
	B	UC	3	3	2	3	3	3	2	6
		HC	3	3	2	3	3	3	2	6
		FC	3	3	2	3	3	3	2	6
	C	UC	3	3	2	3	3	3	2	6
		HC	3	3	2	3	3	3	2	6
		FC	3	3	2	3	3	3	2	6
9.5mm	A	UC	3	3	2	3	3	3	2	6
		HC	3	3	2	3	3	3	2	6
		FC	3	3	2	3	3	3	2	6
	B	UC	3	3	2	3	3	3	2	6
		HC	3	3	2	3	3	3	2	6
		FC	3	3	2	3	3	3	2	6
	C	UC	3	3	2	3	3	3	2	6
		HC	3	3	2	3	3	3	2	6
		FC	3	3	2	3	3	3	2	6

UC – Unconditioned Specimens
HC – Half Conditioned Specimens (12 hours of Conditioning)
FC- Full Conditioned Specimens (24 hours of Conditioning)
* Number of Replicates
Total Number of Test Specimens:
450 (if performance testing on mixtures with one anti-stripping agent is conducted)
594 (if performance testing on mixtures with two anti-stripping agents is conducted)

Anticipated Benefits and Outcomes

The proposed study will provide a simple, reasonable and dependable method for mix design and performance evaluation of Superpave mixtures. The minimum tensile strength criteria developed from different correlations could be used along with the TSR values as a part of the Superpave mix design criteria.

Recommendations for Implementation and Technology Transfer

In this study, a minimum tensile strength would be calculated at a given traffic level for fatigue life and an allowable rut depth for rutting. The tensile strength and TSR values measured for the evaluation of moisture sensitivity could be used for evaluating the mixture's performance. The results and recommendations of the study could be easily implemented into practice.

Resources to be supplied by NCDOT

The amount of raw materials required will be decided in consultation with NCDOT.

Equipment and Facilities

A state-of-the-art equipment related to the proposed research project is available in the construction materials research laboratories at NCSU. A fixture for conducting the dynamic ITS test will be either procured or fabricated as a part of this research project.

Time Requirements

The duration of the proposed research project is 24 months. It is anticipated that the items of work will proceed according to the work schedule in Table 3 . As the MTS and the Shear Tester would be used by several researchers on different research projects, the availability of this equipment is not on continuous basis and has to be scheduled to accommodate other on-going research work.

Qualifications and Accomplishments of Researcher

Dr. Khosla has been on the faculty of Civil Engineering at NCSU for the last 23 years and currently holds a position of a full professor in the Department. He has been an active researcher and has been a Principal Investigator on projects with total funding in excess of $6.0 million. These research projects have been funded through NSF, FHWA, USDOT, NCHRP, and NCDOT. Dr. Khosla is very familiar with the design and performance of asphaltic mixtures and pavements and is eminently qualified to undertake the proposed research study.

List of Related Publications

1. Superpave Level 1 Mix Design, SP-2, Asphalt Institute, Lexington, KY.
2. Taylor, M. A. and N. P. Khosla. "Stripping of Asphalt Pavements: State of the Art." Transportation Research Record 911. TRB, National Research Council, Washington, DC, 1983.
3. Khosla, N. P., Brian Birdsall, and S. Kawaguchi, "Evaluation of Moisture Susceptibility of Asphalt Mixtures – Conventional and New Methods," Transportation Research Record No. 1728, 2000.
4. Button, JW, Perdomo, D, Lytton, RL, "Influence of Aggregate on Rutting in Asphalt Concrete Pavements, " Transportation Research Record 1259, TRB, National Research Council, Washington, DC, 1990
5. Brown E.R. and Bassett, C.E., " Effects of Maximum Aggregate Size on Rutting Potential and Other Properties of Asphalt-Aggregate Mixtures," Transportation Research Record 1259, TRB, National Research Council, Washington, DC, 1990

TABLE 3 – PROPOSED WORK SCHEDULE